1931

STATE COLLEGE OF WASHINGTON
AGRICULTURAL EXPERIMENT STATION
Pullman, Washington

Division of Plant Pathology

The Effect of Certain Potato and Tobacco Viruses on Tomato Plants

by

Grover Burnett and Leon K. Jones

BULLETIN NO. 259
(Technical Paper)
December, 1931

BOARD OF REGENTS

W. A. Ritz, President ..... Walla Walla, Wash.
Walter R. Rowe ..... Naches, Wash.
A. W. Davis ..... Spokane, Wash.
F. J. Wilmer ..... Rosalia, Wash.
J. H. Hulbert ..... Mount Vernon, Wash.
E. O. Holland ..... (President of the College, Secretary, ex-officio)

EXPERIMENT STATION STAFF

E. O. Holland, Ph.D., President — Edward C. Johnson, M.A., Director
Wm. C. Kruegel, B.A., Treasurer

Agricultural Engineering

L. J. Smith, M.E., Agricultural Engineer in Charge.
H. L. Garver, E.E., Investigator, Farm Electricity.[1]
P. C. McGrew, B.S., Agricultural Engineer. U. S. D. A.[2]

Agronomy

E. G. Schafer, M.S., Agronomist in Charge.
E. F. Gaines, D.Sc., Cerealist.[2]
A. L. Hafenrichter, Ph.D., Asst. in Farm Crops.
S. C. Vandecaveye, Ph.D., Soil Biologist.
L. C. Wheeting, Ph.D., Associate in Soils.
Baker, G. O., M.S., Assistant in Soils.
O. E. Barbee, M.S., Asst. in Farm Crops.
Orval A. Vogel, M.S., Agent, U.S.D.A.
H. P. Singleton, M.S., Associate in Agronomy, Irrigation Branch Station, Prosser.
Carl A. Larson, Ph.D., Specialist in Irrigation Investigations, Irrigation Branch Station, Prosser.[2]
Harley Jacquot, B.S., Asst. in Agronomy, Adams Branch Station, Lind.
W. A. Rockie, B.S., Scientist in Soil Erosion. U. S. D. A.[2]

Animal Husbandry

Howard Hackedorn, B.S., Animal Husbandman in Charge.
Jerry Sotola, M.S., Asst. Animal Husbandman.

Chemistry

J. L. St. John, Ph.D., Chemist in Charge.
Otto Johnson, M.S., Assistant Chemist.
Kermit Groves, Ph.D., Assistant Chemist.

Dairy Husbandry

E. V. Ellington, B.S., Dairy Husbandman in Charge.
H. A. Bendixen, M.S., Associate Dairy Husbandman.
C. C. Prouty, M.S., Associate Dairy Bacteriologist.
J. C. Knott, M.S., Superintendent Official Testing.
R. E. Hodgson, M.S., Assistant Dairy Husbandman, Western Washington Experiment Station, Puyallup.

Entomology & Zoology

R. L. Webster, Ph.D., Entomologist in Charge.
Anthony Spuler, M.S., Assoc. Entomologist.
Arthur J. Hansen, M.S., Assistant Entomologist, Western Washington Experiment Station, Puyallup.

Farm Management & Agricultural Economics

Rex E. Willard, B.S., Agric. Economist in Charge.
E. F. Dummeier, Ph.D., Agric. Economist.
Chester C. Hampson, M.A., Assistant Agricultural Economist.
E. F. Landerholm, M.S., Asst. in Farm Management.
A. A. Smick, M.A., Asst. in Rural Sociology.

Home Economics

Florence Harrison, A.M., Home Economist in Charge.
Evelyn H. Roberts, M.S., Research Specialist in Home Economics.
VeNona Swartz, M.S., Research Specialist in Foods and Nutrition.

Horticulture

E. L. Overholser, Ph.D., Horticulturist in Charge.
O. M. Morris, M.S., Horticulturist.
F. L. Overley, M.S., Associate in Horticulture, Wenatchee.
C. L. Vincent, M.S., Asst. Horticulturist.
L. L. Claypool, B.S., Asst. Horticulturist, Irrigation Branch Station, Prosser.

Plant Pathology

F. D. Heald, Ph.D., Plant Pathologist in Charge.
L. K. Jones, Ph.D., Assoc. Plant Pathologist.
C. S. Holton, M.S., Agent, U.S.D.A.[2]

Poultry Husbandry

John S. Carver, B.S., Poultry Husbandman in Charge.
Donald Brazie, M.S., Asst. Poultry Husbandman.

Veterinary Science

J. W. Kalkus, D.V.S., Veterinarian in Charge, Western Wash. Exp. Station, Puyallup.
C. E. Sawyer, D.V.S., Research Veterinarian, Western Washington Experiment Station, Puyallup.

Branch Stations

H. M. Wanser, M.S., Supt. Adams Branch Station, Lind.
H. P. Singleton, M.S., Superintendent, Irrigation Branch Station, Prosser.
D. J. Crowley, B.S., Specialist in Cranberry Investigations, Cranberry Investigations Laboratory, Long Beach.

---

[1] In cooperation with the State Committee on the Relation of Electricity to Agriculture.
[2] In cooperation with the United States Department of Agriculture.

TABLE OF CONTENTS

Introduction 5

Description of viruses 8

- The latent virus disease 8
- Tobacco mosaic 9
- The veinbanding virus disease 9
- The streak disease 10
- Rugose mosaic 11
- Crinkle mosaic 11
- Leaf roll 11
- Spindle tuber 11
- Miscellaneous potato virus diseases 12

Materials and methods 12

The prevalence of the latent virus 14

The veinbanding virus 19

The effect of various viruses upon healthy and veinbanding-virus-infected Early Rose potatoes 20

The use of macerated tuber tissue as inoculum 22

Comparative symptoms and longevity tests with various virus diseases of potato 23

The spread of certain virus diseases of tomato in the field 33

Summary 34

Literature cited 37

The Effect of Certain Potato and Tobacco Viruses on Tomato Plants

By
Grover Burnett and Leon K. Jones

INTRODUCTION

Certain virus diseases of the potato and tobacco are known to be readily transmissible to the tomato and may cause severe losses. A few of these diseases, when found in combination on greenhouse-grown tomatoes, may cause almost complete destruction of the crop. It was deemed advisable, therefore, to study the inter-transmission of certain virus diseases of the tomato, potato and tobacco.

It was first demonstrated by Clinton (8)[1] that tobacco mosaic was transmissible to tomato from tobacco and vice versa. This is perhaps the first definite information that common tobacco and tomato mosaic are identical. In 1910, it was concluded by Johanna Westerdijk (41) that tomato mosaic was infectious on tomatoes, but that it was not communicable to tobacco. She was unable to transmit the mosaic disease of tobacco to healthy tomato by artificial inoculation. It is questionable if she was working with the same disease since Allard (1) and more recent investigators consider common tobacco mosaic and tomato mosaic to be identical.

Johnson (18) has shown the complexity of the tobacco virus situation by pointing out that a number of apparently distinct viruses are capable of producing distinct symptoms on tobacco. He lists and describes the following 19 virus diseases: severe tobacco mosaic types 1 and 2; mild types 1 and 2; yellow, white, and ring mosaics; etch, etch plus, severe etch; veinbanding; coarse etch; ringspot; healthy potato virus; cucumber mosaic types 1, 2, and 3; healthy potato virus plus veinbanding (spot necrosis); and cucumber mosaic type 3 plus veinbanding. All of these viruses are capable of being transmitted to tomato by the rubbing method except true tobacco ringspot and coarse etch. The following types of viruses were also secured by him from naturally infected tomato: severe tobacco mosaic type 1, mild tobacco mosaic type 1, etch, etch plus, severe etch, coarse etch, veinbanding, and the "healthy potato" virus.

The transmission of certain virus diseases of potato to tomato was reported by Quanjer (26). He transmitted leaf roll, interveinal mosaic, aucuba mosaic, common mosaic and crinkle to tomato by grafting. As

[1] Reference made by number to "Literature Cited."

pointed out by Johnson (21), crinkle as used by Quanjer is probably the same as Schultz and Folsom's (28) rugose mosaic. In 1923, employing leaf mutilation methods, Schultz and Folsom (28) indicated that the tomato was susceptible to potato mosaic. Fernow (11) transferred but one disease from potatoes affected by various mosaic diseases, to other hosts, including tomato and tobacco. He designated this as virus B which is probably the same as the latent virus mentioned in this paper. In more comprehensive tests, Johnson (19 and 20) was the first to demonstrate that at least two different viruses are commonly, if not universally, present in most standard varieties of potatoes. He tested nine different varieties which were secured from widely different sources throughout the United States. When the potato viruses were transferred to tobacco the three diseases, mottle, spot necrosis and ringspot, were produced. He was of the opinion that the two former were perhaps different expressions of the same disease. It was demonstrated by Olitsky and Northrop (23) that diseased or apparently healthy potatoes carried a virus which could be transferred to tobacco or tomato.

In 1928, Henderson-Smith (13) was unable to obtain a disease in tomato by inoculating with material from healthy potatoes, but a definite and characteristic disease was regularly produced by inoculation with material from potatoes infected with mosaic. He obtained two types of symptoms on tomato (mottle and spot necrosis) and suggests that potato mosaics may be made up of a mixture of two viruses. This spot necrosis is apparently the same as Johnson's (19) ringspot and the virulent latent to be discussed in this paper.

From a study of the information contained in four articles by Smith (30, 31, 32 and 33), it appears that he demonstrated the transmissibility of the veinbanding virus as described by Johnson (18), by *Myzus persicae* Sulz. from mosaic infected potato plants, (probably rugose mosaic). An interpretation of his studies also shows that both the latent virus and the veinbanding virus could be transmitted to tobacco and tomato by mechanical maceration methods.

It was shown by Johnson (19) that extracts from 18 different species of healthy plants, mostly of the solanaceous family, including potato seedlings, when inoculated into tobacco failed to yield any symptoms of disease. It has been further demonstrated by Burnett and Jones (6 and 7) that apparently healthy commercial potatoes are virus carriers which is not true of potato seedling stock. In further tests, the authors (7), by repeated trials, found one tuber of the Early Rose variety which failed to show the presence of any virus.

In a recent article by Valleau and Johnson (38) it is demonstrated that at least two distinct viruses are concerned in the virus complex of rugose mosaic of potatoes. One of these viruses, which is readily transmitted to tobacco by *Myzus persicae*, is called veinbanding. The other or

latent virus, found in potatoes affected with other virus diseases as well as in apparently healthy commercial potatoes, is not transmitted by the insect. Both viruses are readily transmitted by mechanical maceration methods. They show that a mixture of the veinbanding virus and the latent virus when inoculated into tobacco plants produces spot necrosis identical with that produced by inoculating tobacco with juice from potato plants affected with rugose mosaic. This same combination of viruses when inoculated to potato seedlings produces a disease similar to rugose mosaic.

Streak, winter blight or stripe disease of tomato has been known since 1890. The first mention of the disease, according to Orton and McKinney (24), was made by Lodeman in 1892, where he found the disease in the greenhouse at Ithaca, New York, during the winter of 1890-91. A more complete account of the disease was given the same year by Bailey (2). He believed that the disease was caused by bacteria. This same view was held by Melhus (22) and later investigations by Paine and Bewley (25) led them to the conclusion that the disease was caused by *Bacillus lathyri*. The disease was attributed to malnutrition by Howitt and Stone (14). Later it was concluded by Stone (34) that the disease was associated with an excess of nitrogen and a deficiency of potash which could be controlled by increasing phosphoric acid and potash.

As early as 1917, Jackson (15) held the view that streak was of a virus nature. That the disease was due to a virus in its most destructive form or that the virus caused necrosis under certain environmental conditions, was advanced by Gardner and Kendrick (12). Dickson (9) concluded that streak is not caused by *Bacillus lathyri*, but by a combination of the potato mosaic virus and the tomato mosaic virus(tobacco mosaic).

That streak is due to the combined viruses of potato mosaic and tobacco mosaic was further shown by Johnson (19), Vanterpool (40), Berkeley (3), Blood (4), Stover (35), Doolittle and Blood (10), and Valleau and Johnson (39). In addition to streak, which is caused by the combined virus mixture, Doolittle and Blood (10) reported two other forms of streak which were of unknown origin, but which gave different symptoms on other solanaceous hosts.

Jarrett (16 and 17) working in England, concluded that glasshouse streak was a symptom of tobacco mosaic and not caused by the combined viruses of potato and tobacco, the latter she termed experimental streak. A virus disease of tomato termed "spotted wilt" producing symptoms which may be confused with streak, has been described in Australia by Brittlebank (5) and Samuel, Bald and Pittman (27). This disease differs primarily from streak in that it has been transmitted only by a species of thrips, *Frankliniella insularis* (Franklin), and has not been transmitted by mechanical maceration methods. Jarrett (17) considers spotted wilt the

same as streak of tomato. This conclusion does not seem justifiable in as much as Dickson (27) now working in Australia, was familiar with streak as it appears in America, as well as spotted wilt in Australia, and considers them to be distinct diseases.

The results of Valleau and Johnson (39) show that they were able to produce streak symptoms on tomato by combining the latent virus of potato with, (1) three strains of tobacco mosaic viruses; (2) three strains of cucumber mosaic viruses; (3) etch, etch plus, severe etch; and (4) by ring mosaic when used alone.

From tests with material of streak sent in from different localities in the state of Washington, it is concluded by the writers that streak as commonly found in greenhouses in this state is caused by the combination of the latent virus of potato and the tomato mosaic virus (tobacco mosaic).

DESCRIPTION OF VIRUS DISEASES

The Latent Virus Disease

The latent virus, depending upon its source and virulence, is capable of producing somewhat variable symptoms. The term "latent" (7), as employed in this paper, refers to the virus secured from apparently healthy potatoes, or potatoes affected with various virus diseases which produce "mottle" of tomato (Plate I, Fig. D) and tobacco (Plate II, Fig. C, and Plate III, Fig. A). This virus may cause a faint mottling on tomato which consists of irregular areas of pale green interveinal tissue. This mottling may be so very faint that at times it may be difficult to recognize, or it may cause irregular, pale green to extremely yellow, chlorotic, interveinal tissue in contrast to the darker green along the larger veins. Necrosis of tomato is rarely evident, but may occur in a mild form as small brown, scattered spots, usually confined to the lower leaves of the plant. There is apparently no dwarfing of the tomato plants affected with this virus. The latent virus referred to in this paper appears to be the same as the mottle virus of tobacco as described by Johnson (19).

The term "virulent latent" employed in this paper, refers to the virus sometimes secured from apparently healthy potatoes, or potatoes affected with other virus diseases, which is capable of causing the following symptoms on tomato and tobacco. It causes white, necrotic, ring and line symptoms on tobacco foliage (Plate III, Fig. C) oftentimes within four days after inoculation. This diseased condition is similar to ring spot as described by Johnson (19) and to the diseased condition caused by the "healthy potato" virus as described by Johnson (18) and Valleau and Johnson (38). The virulent latent virus produces spot necrosis of tomato (Plate IV, Fig. B) as

well as more extreme mottling than is the case with the latent virus. From 4 to 12 days after inoculation the tomato plants usually exhibit a mottle similar to the less virulent form and in addition small (1-5 mm.) necrotic, brown lesions on the older leaves of the plant often appear. In extreme cases, the necrotic symptoms on tomato produced by the virulent latent virus may be confused with the symptoms of streak. However, the virulent latent virus produces lesions on the older foliage, progressing up the plant. The virulent latent virus does not cause black, pencil line streaks on the stems nor a necrosis of the young tip foliage as is the case with the streak disease. According to Valleau and Johnson (38) the virulent latent virus differs from the latent virus only in its increased virulence and they are both considered as the "healthy potato" virus. It is still questionable whether the latent and the virulent latent viruses are one and the same or distinct. However, in this paper they will often be referred to as distinct viruses in order to clarify the discussion.

The latent viruses of potato are very readily transmitted by mechanical maceration methods and apparently are not transmitted by aphids. The appearance of necrotic lesions in the foliage of tomato caused by the latent or virulent latent viruses is spoken of as spot necrosis of tomato (Plate IV, Fig. B) in these investigations.

Tobacco Mosaic

This disease is characterized by prominent mottling, consisting of raised, dark green, blister-like areas produced irregularly in the pale green tissue of the leaves. The new leaves that form after infection may be narrow and pinched at the tip. Common tobacco mosaic referred to as "tobacco virus 1" by Johnson (20) was used in these experiments. The disease produced by this virus is also referred to by Johnson (18) as "severe mosaic type 1."

The symptoms of tobacco mosaic on tomato are quite similar to those produced on tobacco.

The Veinbanding Virus Disease

The veinbanding virus used in these studies was secured from a virus-free Early Rose potato which contracted the virus when grown under field conditions. The virus was probably transmitted to the plant in the field by aphids. The symptoms on potato produced by the veinbanding virus consist of irregular, pale green areas between the veins (Plate V, Fig. D). This mottling often becomes very distinct and approaches the symptoms produced by crinkle mosaic as described by Schultz (29).

The veinbanding virus produces very mild symptoms on tomato. The leaves of affected plants have veins that are pale green and a

barely visible mottling consisting of irregular pale green areas between the veins. These symptoms are often not sufficiently pronounced for definite diagnosis. The veinbanding virus used in these studies was compared with the veinbanding virus kindly furnished by E. M. Johnson. The symptoms produced by the two viruses were similar on tomato and tobacco.

From a study of the symptoms produced on tobacco by the veinbanding virus (Plate II, Fig. A) and the mottle latent virus (Plate II, Fig. C and Plate III, Fig. A) it is apparent that the symptoms produced by the two viruses are very similar. Also that the term veinbanding could more appropriately be applied to the disease produced by the mottle latent virus and mottle to the disease produced by the veinbanding virus. The veinbanding virus was first described by Valleau and Johnson (37) as "vein margin" and later termed veinbanding by Johnson (18).

The Streak Disease

This disease of tomato as described by Vanterpool (40) is caused by a combination of a potato virus and the tomato mosaic virus. An abundance of dark brown to black, irregular, necrotic areas, 1 mm. to 1 cm. in diameter are produced on the foliage (Plate I, Fig. A). In extreme cases these necrotic spots coalesce and entire leaflets and leaves are killed. Black to brown, somewhat sunken, elongated lesions are produced on the stem and petioles. Extreme dwarfing of young plants is very common and often the young growing tip of the plant is killed within 10 to 14 days after inoculation. When older plants become affected, extreme necrosis of foliage develops for two or three nodes adjacent to the point of inoculation. The foliage below the point of inoculation remains relatively normal in appearance. The foliage produced above the point of inoculation becomes dwarfed and for a time may show only the symptoms of tobacco mosaic. Later such foliage becomes more or less spotted with irregular, brown lesions 1-5 mm. in diameter. The fruit set is greatly reduced above the point of inoculation. Fruits produced on infected plants are often more or less spotted with brown, raised, greasy lesions, 2-5 mm. in diameter (Plate IV, Fig. C). These brown lesions are superficial on the fruit seldom extending below the epidermal cells. In these investigations the term streak is employed to represent that diseased condition produced on tomato by the combination of the tobacco mosaic virus and the latent or virulent latent virus of potato.

The streak disease viruses when transferred to tobacco produce extreme dwarfing of the plants and necrosis of the foliage that may cause the death of young plants. This necrosis of tobacco plants produced by the streak viruses is referred to as leaf necrosis in these investigations.

Rugose Mosaic

Rugose mosaic of potato is characterized by mottling, dwarfing, rugosity and the appearance of various types of necrotic areas on the stem and foliage of the affected plants (Plate V, Fig. B). In this paper the term is used as employed by Schultz and Folsom (*29*).

The transfer of the rugose mosaic viruses to young tobacco plants produces necrotic symptoms (Plate III, Fig. B) referred to as spot necrosis by Johnson (21) and by Valleau and Johnson (38). Chlorotic spots appear on inoculated leaves which later may become brown necrotic lesions. Similar necrosis usually appears later on newly developed foliage. Ring and line necrotic areas that are characteristic of the virulent latent disease may also appear on the foliage (Plate III, Fig. C).

Tomato plants affected with this disease at first may show only a faint mottle of the foliage similar to that produced by the latent or virulent latent viruses. The light green interveinal tissue gradually becomes pale yellow, especially on the older leaves. Small, necrotic, brown spots appear in the older leaves (Plate I, Fig. B). Yellowing and death of the lower leaves may follow. This diseased condition may be confused with streak of tomato (Plate I, Fig. A). However, it differs from streak primarily because the necrosis is limited to the older foliage, while streak causes necrosis of the young tip foliage and stems. In these investigations the disease of tomato produced by the rugose mosaic viruses from potato is referred to as spot necrosis of tomato (Plate I, Fig. B).

Crinkle Mosaic

This disease on potato is characterized by distinct mottling of foliage followed by wrinkling or ruffling and dwarfing of leaflets and generally stunting of growth. Leaves may sometimes curl or roll to some extent. No necrosis is produced. The term is used according to Schultz and Folsom (*29*) and Johnson (21).

Leaf Roll

The distinguishing characters of this disease on potato include distinct rolling upward and rigidity, especially of the lower leaves, dwarfing, chlorosis, and some burning. The term is used according to Schultz and Folsom (*29*).

Spindle Tuber

Spindle tuber of potato produces spindling stems and upright, somewhat darker green and slightly rugose and dwarfed foliage. The term is used according to Schultz and Folsom (*29*).

Miscellaneous Potato Virus Diseases

Other potato virus diseases were tested on tomato. Mild mosaic and unmottled curly dwarf of potato are terms used to designate diseases as described by Schultz and Folsom (29). Witches' broom and super-mild mosaic are terms used to designate diseases as described by Young and Morris (42 and 43).

MATERIALS AND METHODS

The experimental work was carried on in the greenhouse and in the field at the State College of Washington, Pullman, Wshington, during the period from September 20, 1929 to June 1, 1931. Tomato, tobacco, and potato seed were started in flats in the greenhouse at a temperature of 65° to 70° F. and transplanted into 2-, 3-, or 4-inch pots in a mixture of approximately 4 parts of Palouse loam, 2 parts of sand and 1 part of well-rotted manure. The John Baer variety of tomato was used in most of the experiments because it is highly susceptible to virus diseases and has a smooth leaf which makes it desirable in observing mosaic symptoms.

Preparatory to making a series of inoculations the virus-containing material, either fresh or dried, was thoroughly macerated by rubbing with a pestle in a mortar. Following maceration the material was diluted about 1 to 10 with distilled water or artesian tap water. The material was again thoroughly mixed and macerated.

As a general rule, each of the inoculated series consisted of 5 plants with 3 to 5 as controls, but in a number of series 20 plants were used with 10 to 20 plants as controls. Inoculations were made by the maceration method, i. e., a new or sterilized pot label was held below and supporting the leaflet or leaf to be inoculated, and the upper surface was rubbed with a piece of sterile absorbent cotton which had been dipped into the inoculum. The leaf was rubbed until it was evident that the leaf tissue had been injured. From 2 to 5 leaves per plant were inoculated in this manner. Immediately following this inoculation the mortar and pestle, as well as the hands, were thoroughly washed with soap and water.

The plants of the control series were then inoculated with tap water from the same mortar as used in making the inoculation with the virus. A fresh pot label and sterile piece of cotton were used when inoculating the control plants. By this method a careful check could be made to determine whether the disease was being carried over to the control plants or to the subsequent series.

Strong and healthy tomato and tobacco plants were inoculated when they had produced from 2 to 5 leaves. Precaution against pos-

sible contamination was taken in the preparation of the inoculum. The following procedure was rigidly followed: The mortar and pestle as well as the hands were thoroughly washed with ivory soap and rinsed with running artesian tap water before and after each inoculation. When placing the inoculated plants on the raised benches, in the greenhouse, following the inoculation, precautions were taken to avoid having one plant touch another. To further avoid danger of contamination, a space of about one foot was left between adjacent series.

Through the courtesy of various scientists working with virus disases, potato tubers carrying virus diseases were received as listed in Table 1. Dry, common tobacco mosaic No. 1 was kindly furnished by James Johnson, Madison, Wisconsin. E. M. Johnson, Lexington, Kentucky, kindly furnished, for comparative studies, several virus diseases in living Burley tobacco plants. Potato seed was secured from Charles F. Clarke, Presque Isle, Maine, and from C. L. Vincent, Pullman, Washington.

All other materials used in the experiments were obtained in the greenhouse from tuber-indexed potatoes or from tomatoes which showed streak or other types of virus troubles.

Table 1. The Source of Certain Virus Diseases

Variety	Virus disease	Source
Bliss Triumph	Spindle tuber	P. A. Young, Bozeman, Mont.
Bliss Triumph	Crinkle mosaic	P. A. Young, Bozeman, Mont.
Bliss Triumph	Unmottled curly dwarf	P. A. Young, Bozeman, Mont.
Bliss Triumph	Witches' broom	P. A. Young, Bozeman, Mont.
Netted Gem	Spindle tuber	P. A. Young, Bozeman, Mont.
Netted Gem	Super-mild mosaic	P. A. Young, Bozeman, Mont.
Idaho Rural	Crinkle mosaic	P. A. Young, Bozeman, Mont.
Burbank	Leaf roll[1]	T. P. Dykstra, Corvallis, Ore.
Bliss Triumph	Rugose mosaic[2]	T. P. Dykstra, Corvallis, Ore.

[1] The leaf roll of Burbank had been transmitted from Bliss Triumph by **Myzus circumflexus.**

[2] The rugose mosaic on Bliss Triumph had been transmitted by **Myzus persicae** from the variety, Earliest-of-all.

Instead of including the control series in each separate table a general summary of results and remarks will be presented. A total of 1,840 tomato plants was used as controls. Of this number, 7 plants were contaminated with tobacco mosaic, 1 in each of 4 different control series, and 3 in another. In the latter series tobacco mosaic became evident within 2 days after inoculation which would indicate

previous contamination. Tomato plants were used in all of the control series and in a number of series tobacco plants were also used. In all, 574 tobacco plants were used as controls. Of this number, 12 plants in 7 different series showed contamination with tobacco mosaic. Five plants in each of 2 series, showed tobacco mosaic within 3 days following inoculation which also indicated previous contamination. In 2 separate series, the cause of 4 of the contaminated plants could be accounted for, since these plants were moved and used a second time as controls. Of the 3 remaining contaminated plants, no other reason could be offered other than accidental contamination. In no case did the subsequent inoculation following these contaminated control series show a carry-over of contamination from the control series.

THE PREVALENCE OF THE LATENT VIRUS

It has been shown by Johnson (19) that apparently healthy potatoes are carriers of viruses. His conclusions based on tests of about 320 apparently healthy tubers were that two different viruses are commonly, if not universally, present in most standard varieties of potatoes. He further demonstrated that potato seedlings and 18 other species of plants, mostly belonging to the family Solanaceae, were free from these viruses. Valleau and Johnson (38) conclude that this virus, which they call the "healthy potato" virus, is universally distributed in so-called healthy potatoes. Investigations by Henderson-Smith (13) and by Smith (30, 31, 32 and 33) have led them to the conclusion that certain varieties of potatoes in England are not carriers of the latent virus. This conclusion is based on the failure of tomato or tobacco plants to show symptoms when inoculated with juice from the apparently healthy potato plants. It is possible that they may have overlooked the mild mottle symptoms often produced by the latent virus. Their statement would be more conclusive had they tested these potato varieties for the possible production of streak on tomato plants by combining the juice of the potato plants with the juice of tobacco mosaic infected plants and inoculating this combination on tomato.

Tests of commercial tuber stock and seedling potatoes were made by the authors to determine the presence of the latent virus. The presence or absence of the latent virus in the potato plants was determined by the production or lack of production of streak of tomatoes when juice of the potato plant was combined with juice of a mosaic infected tobacco plant and these combined viruses inoculated into tomato. In these investigations the combination of the latent virus or virulent latent virus and the tobacco mosaic virus always produced streak, when inoculated into tomato plants under normal growing conditions.

Fifty-two potato seedlings were tested, none of which showed the presence of the latent virus (Table 2). Six varieties of apparently healthy commercial potatoes were tested, including the following: Beauty of Hebron, Burbank, Early Rose, Netted Gem, White Rose and Wisconsin Pride (Table 2). Fifty-five tubers were tested on tomato with the potato foliage alone. These 55 and 50 additional tubers were tested on tomato in combination with tobacco mosaic. One tuber of the Early Rose variety failed to show the presence of the latent virus (Tables 3 and 4) which was designated in the tests as tuber "B 1."

Further tests to determine the presence of the latent virus in apparently healthy potatoes were made during the spring of 1931. These tests were made on commercial stock sent to the Washington State Experiment Station for tuber indexing by 9 different growers located in different localities of the state of Washington.

Apparently healthy potato plants were produced from 550 of the tubers indexed: 437 of the Netted Gem variety; 70 Burbank; and 43 Early Rose.

Macerated foliage from each of these plants was combined with macerated tobacco mosaic tissue and inoculated to young tomato plants. In every case streak developed on the tomato plants. These results show that the latent virus was present in each of the 550 tubers tested.

Table 2. Results of Inoculation Tests on Tomato with Foliage from Seedlings and from Apparently Healthy Commercial Potato Tuber Stock

Source of inoculum and variety tested	Potato foliage alone			Potato foliage plus tobacco mosaic			
	No. of tubers tested	No. of plants inoculated	No. of plants showing mottle	No. of tubers tested	No. of plants inoculated	No. of plants showing streak	No. of plants showing mottle
Seedlings	52	250	0	52	250[1]	0	0
Beauty of Hebron	12	60	60	12	60	57	2
Burbank	3	15	15	14	70	70	0
Early Rose	20	100	75[2]	29	148	97[2]	13[2]
Netted Gem	10	55	55	36	210	210	0
White Rose	6	35	35[3]	6	35	35	0
Wisconsin Pride	4	20	20	8	45	45	0
Totals	107	535	260	157	818	514	15

[1] All plants showed tobacco mosaic.
[2] Reduction in number of diseased plants is due to the use of the healthy tuber as a source of inoculum.
[3] Five plants also showed spot necrosis.

Table 3. Results of Inoculation Tests on Tomato with Healthy Early Rose (B 1) Potato Foliage

Date of inoculation	Potato foliage alone			Potato foliage plus tobacco mosaic		
	No of trials	No. of plants inoculated	No. of plants diseased	No. of trials	No. of plants inoculated	No. of plants diseased
March 19, 1930	1	5	0	1	5	5T[1]
April 14, 1930[2]	1	5	0	1	5	5T
May 6, 1930	1	5	0	1	5	5T
July 11, 1930[3]	0	0	0	1	8	8T
Totals	3	15	0	4	23	23T

[1] Tobacco mosaic.

[2] Macerated tuber tissue.

[3] Macerated foliage from plants grown in the field. Inoculations on plants under field conditions.

Table 4. Results of Inoculation Tests on Tomato with Foliage from Five Hills Produced in the Field from the Healthy Early Rose Potato (B 1)

Source of inoculum	Potato foliage alone			Potato foliage plus tobacco mosaic		
	No of trials	No. of plants inoculated	No. of plants diseased	No. of trials	No. of plants inoculated	No. of plants diseased
Hill A	1	10	0	1	10	9T[1]
Hill B	1	10	0	1	10	10T
Hill C	1	10	0	1	10	2T
Hill D	1	10	0	1	10	10T
Hill F[2]	1	10	8M 2SN	1	10	9S 1T
Totals	5	50	8M 2SN	5	50	9S 32T

[1] M=Mottle; SN=Spot necrosis; T=Tobacco mosaic; S=Streak.

[2] Hill F produced from B 1 healthy potato was inoculated with rugose mosaic August 9, 1930. All tests were made October 1, 1930.

Six hills of potatoes from the healthy tuber (B 1) were then produced in the field during the 1930 growing season. Two hills were caged (C and E) with insect-proof cages, one of which (C) was not inoculated. The other caged hill (E) and the uncaged hill (F) were inoculated on August 9, 1930 with rugose mosaic obtained from T. P. Dykstra of Oregon. On October 1, 1930, the foliage from the 6 hills, except hill E which had died, was tested for the presence of the latent virus (Table 4).

Hills A, B, C, and D again failed to show the presence of the latent virus when the macerated potato foliage was used alone or in combination with tobacco mosaic. Hill F, which had been inoculated with rugose mosaic, showed the presence of the latent virus and also gave spot necrosis symptoms on tomato typical of rugose mosaic.

Table 5. Results of Inoculation Tests on Tomato and Tobacco with Foliage from the Progeny of the Healthy Early Rose Potato

Source of inoculum	Potato foliage alone						Potato foliage plus tobacco mosaic		
	On tomato			On tobacco			On tomato		
	No. of trials	No. of plants inoculated	No. of plants diseased	No. of trials	No. of plants inoculated	No. of plants diseased	No. of trials	No. of plants inoculated	No. of plants diseased
Hill A									
Tuber 1	1	5	0	1	5	5VB[1]	1	5	5T
Tubers 2, 6, 9	-	-	-	-	-	-	3	15	15T
Hill B									
Tuber 1	1	5	0	1	5	5VB	1	5	5T
Tubers 2 to 10	-	-	-	-	-	-	9	45	45T
Hill C									
Tuber 2	1	5	0	1	5	0	1	5	5T
Tubers 4 & 7	-	-	-	-	-	-	2	10	10T
Hill D									
Tuber 2	1	5	0	1	5	5VB	1	5	5T
Tubers 3 to 8 inc. & 10	-	-	-	-	-	-	7	35	35T
Totals	4	20	0	4	20	15VB	25	125	125T

[1] V.B.=Veinbanding; T=Tobacco mosaic.

The tubers which were produced from the 6 hills, in the field, as progeny of the healthy B 1 tuber, were indexed in the greenhouse and tested for the presence of virus diseases (Tables 5 and 6). Tests were run on tomato and tobacco plants similar to previous tests on tomato plants alone. One tuber from each hill, A, B, C, and D, was tested with the potato foliage alone on 5 tomato and 5 tobacco plants and again in combination with tobacco mosaic on 5 tomato and 5 tobacco plants, none of which showed the presence of the latent virus (Table 5). In addition, the foliage from 3 tubers of hill A, 9 tubers of hill B, 2 tubers of hill C, and 7 tubers of hill D, was tested on tomato in combination with tobacco mosaic (Table 5). Of the 25 tubers tested, on 125 tomato plants, streak did not develop, while these 125 tomato plants showed tobacco mosaic. The results of these tests indicate that the latent virus was not present in these tubers.

Table 6. Results of Inoculation Tests on Tomato and Tobacco with Foliage from the Progeny of the Healthy Early Rose Potato which Had Been Inoculated with Rugose Mosaic.[1]

Source of inoculum	Potato foliage alone				Potato foliage plus tobacco mosaic	
	On tomato		On tobacco		On tomato	
	No. of plants inoculated	No. of plants diseased	No. of plants inoculated	No. of plants diseased	No. of plants inoculated	No. of plants diseased
Hill E						
Tuber 1	5	5SN[2]	5	4SN 1R	5	5S
Tuber 2	5	5SN	5	5SN	5	5S
Tuber 3	5	5SN	5	4SN 1R	5	5S
Tuber 6	5	5M	5	5R	5	5S
Hill F						
Tuber 1	5	5SN	5	1SN 4R	5	5S
Tuber 2	5	5SN	5	3SN 2R	5	5S
Tuber 4	5	5SN	5	4SN 1R	5	5S
Tuber 5	5	5SN	5	3SN 2R	5	5S
Tuber 7	5	5SN	5	4SN 1R	5	5S
Totals	45	40SN 5M	45	28SN 17R	45	45S

[1] Hills E and F produced in the field from the B 1 tuber were inoculated with rugose mosaic August 9, 1930.

[2] SN=Spot necrosis; R=Virulent latent; M=Mottle; S=Streak.

THE VEINBANDING VIRUS

The tests on tobacco plants with foliage from one tuber each, produced in hills A, B, and D as progeny of the healthy B 1 tuber, revealed the presence of a virus, other than the latent virus. This virus was not present in tubers from hill C (Table 5). This virus gave the same symptoms on tobacco as those described as veinbanding by Johnson (18). This similarity was further proven in comparative tests with veinbanding kindly furnished by E. M. Johnson.

When the veinbanding virus is combined with the virulent latent virus it produces typical spot necrosis of tobacco and extreme mottle and often spot necrosis of tomato. Tobacco plants inoculated with rugose mosaic develop spot necrosis, while tomato plants show extreme mottle and often spot necrosis. It would then appear that the veinbanding virus present in tubers from hills A, B, and D, when combined with the virulent latent virus produced symptoms comparable to rugose mosaic. Valleau and Johnson (38) also conclude that the veinbanding virus plus the latent virus produces a disease of potato similar to rugose mosaic. The virulent latent virus was obtained by drying tomato foliage for 286 days which had previously been inoculated with rugose mosaic. The virulent latent virus, thus obtained, gave typical ring and line symptoms on tobacco even after numerous successive transfers through tobacco (Plate III, Fig. C). It is quite certain that this virulent latent virus is free from other virus complexes since it retains its identity by consistently producing ring and line symptoms of tobacco, mottle and often extreme spot necrosis of young tomatoes, and typical streak of tomatoes when combined with tobacco mosaic.

Referring to Table 5, it will be noted that 5 tobacco plants, when inoculated with macerated foliage of plants from each series (hill A, tuber 1; hill B, tuber 1; and hill D, tuber 2) produced veinbanding. Tobacco plants when inoculated with macerated foliage from hill C, tuber 2, failed to show any virus disease symptoms. After the veinbanding symptoms became evident, 3 tobacco and 3 tomato plants from each of the 3 above mentioned series that showed veinbanding, were inoculated with the virulent latent virus. Seven of the 9 tomato plants inoculated with the virulent latent virus produced severe spot necrosis while 2 plants showed only mottle. Eight of the 9 tobacco plants produced spot necrosis, similar in all respects to plants inoculated with rugose mosaic, while 1 plant inoculated with macerated foliage from hill B, tuber 1, gave only mottle symptoms. The 3 tobacco plants inoculated with macerated foliage from hill C, tuber 2, produced only virulent latent symptoms, which again indicates the absence of the veinbanding virus in hill C in contrast to its presence in hills A, B, and D. Since hills A, B, and D were not caged in the field

and hill C was caged, it appears that the veinbanding virus was transmitted to plants in hills A, B, and D by insects. This is in conformity with the conclusions of Smith (30, 31, 32 and 33) and also of Valleau and Johnson (38) that the veinbanding virus is readily transmitted by *Myzus persicae.*

THE EFFECT OF VARIOUS VIRUSES UPON HEALTHY AND VEINBANDING-VIRUS-INFECTED EARLY ROSE POTATOES

Tubers from the 6 hills (A to F inclusive) were indexed in pots in the greenhouse. Following is a discussion of preliminary results obtained when some of these plants were inoculated with certain virus diseases. Tubers from hills A, B, and D, when tested (Tables 4, 5 and 6) failed to show the presence of the latent virus but showed the presence of the veinbanding virus. Potato plants produced from these tubers had a distinct mottling of the foliage. This mottle (Fig. 5, D) is characterized by rather large, diffused, light green, mottled areas between the veins in contrast to an indefinite darker green along the veins and veinlets. When this foliage was used as inoculum on tobacco plants, veinbanding was produced and when combined with the latent virus, spot necrosis of tobacco was produced. Tubers from hills E and F which had been inoculated with rugose mosaic in the field produced plants with typical rugose mosaic symptoms.

Two plants from hill A, and 5 plants from hill B were inoculated with the virulent latent virus. All plants produced rugose mosaic symptoms within 15 to 20 days. The foliage showed rugose mosaic symptoms with mottling and rugosity, and irregular, brown, dead, necrotic spots on the foliage, varying in size from minute spots up to 2 to 3 cm. in diameter. These brown spots often resemble early blight lesions but do not have the concentric ringing. Dark brown streaks often appear on the stems. The floral parts show necrosis and killing with streak or brown necrotic spots. At first the lower leaves show the dead and brown necrotic lesions. This is followed by a drooping of the leaf, which may become entirely necrotic, dry and shriveled, and finally falls from the plant. Early infection produces severe dwarfing, slow growth, and often death of the plant.

Six plants produced from hill B were inoculated with the latent virus, which was secured from a White Rose potato. The symptoms produced were similar, but not as severe, as those produced by the virulent latent virus. It, however, produced rugosity, wrinkling, mottling, irregular, brown necrotic spots, streaking, leaf dropping, and dwarfing.

Two plants from hill A, when inoculated with a combination of these two latent viruses gave similar symptoms but no more severe than when the virulent latent virus was used alone.

EXPLANATION OF PLATES

Plate I. Tomato leaves: A, streak produced by inoculating tomato plants with the latent virus from apparently healthy potato plus common tobacco mosaic; B, spot necrosis produced by inoculating tomato plants with rugose mosaic of potato; C, healthy control; D, mottle produced by inoculating tomato plants with macerated foliage of potato plants carrying leaf roll and the latent virus.

Plate II. Leaves of tobacco: A, veinbanding obtained from foliage of Early Rose potato (B 1-D 7); B, healthy leaves; C, mottle produced on tobacco plants by inoculating with macerated potato foliage carrying crinkle mosaic and the latent virus.

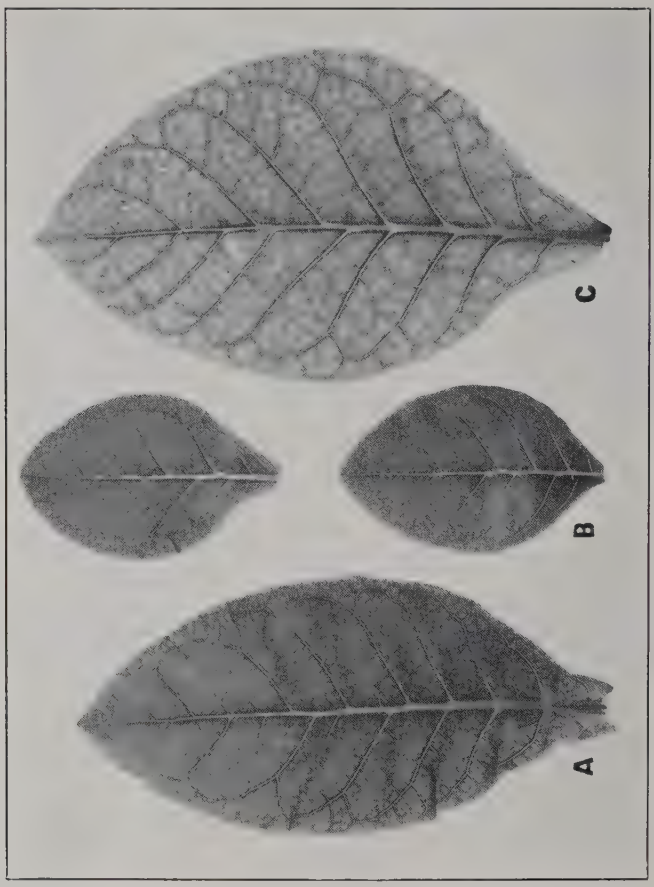
Plate III. Leaves of tobacco: A, mottle produced by the latent virus from apparently healthy potato; B, spot necrosis produced by rugose mosaic of potato; C, ring and line pattern produced by the virulent latent virus of potato.

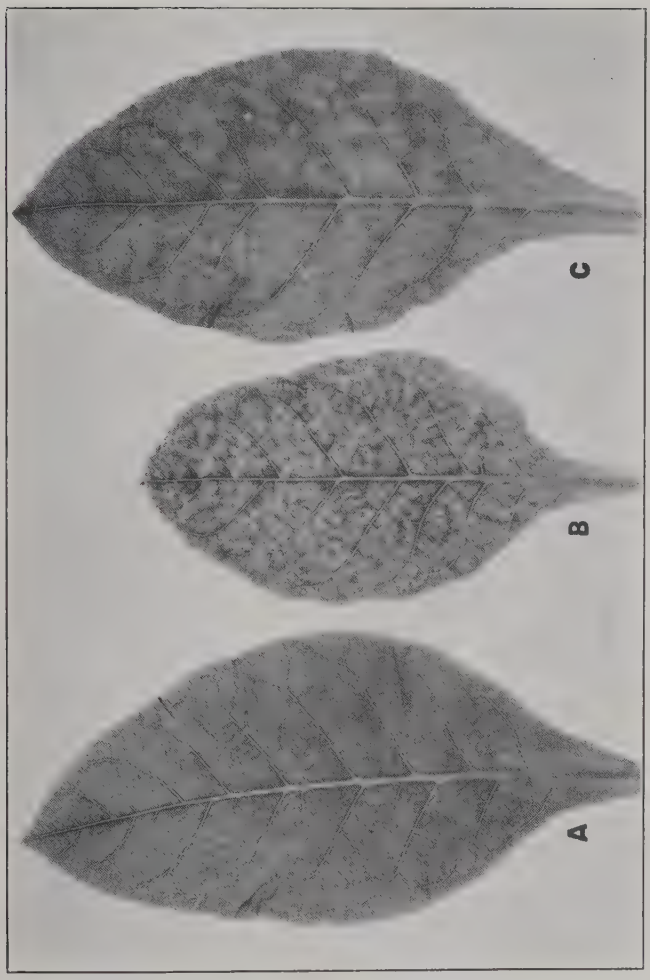
Plate IV. A, Tomato leaflet from healthy control plant; B, spot necrosis produced on older tomato leaflets by inoculation with the virulent latent virus; C, tomato fruit showing greasy, brown raised lesions produced on streak affected plants.

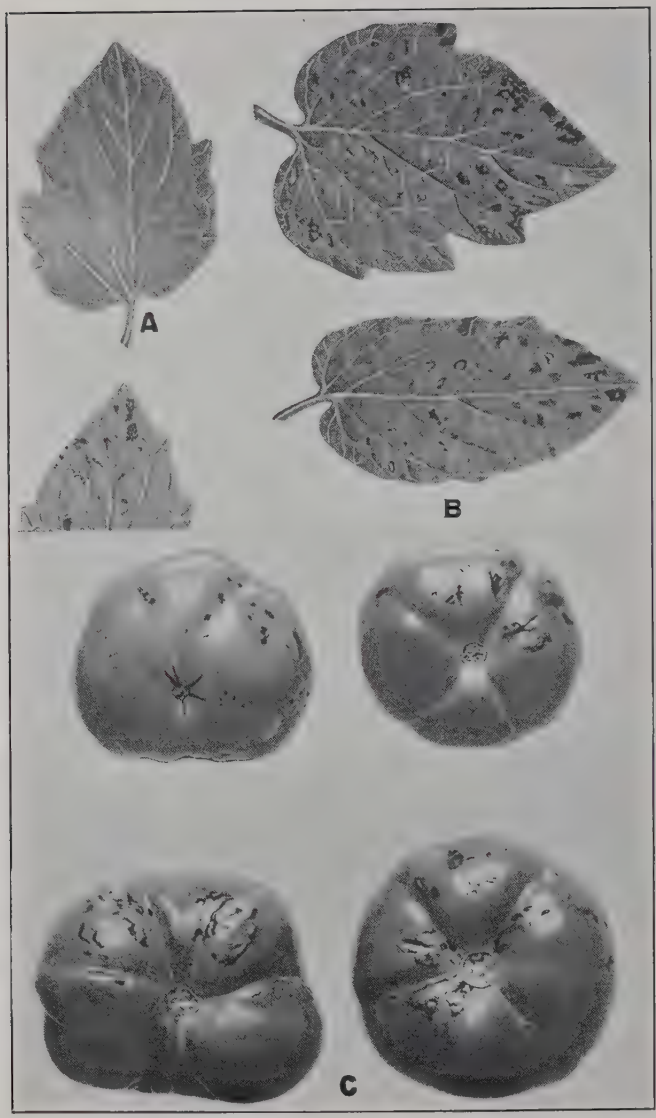
Plate V. Potato leaves: A, an apparently healthy Early Rose leaf affected with the latent virus; B, Early Rose leaf affected with rugose mosaic; C, healthy leaf from a potato seedling; D, leaf from a seedling plant affected with the veinbanding virus.

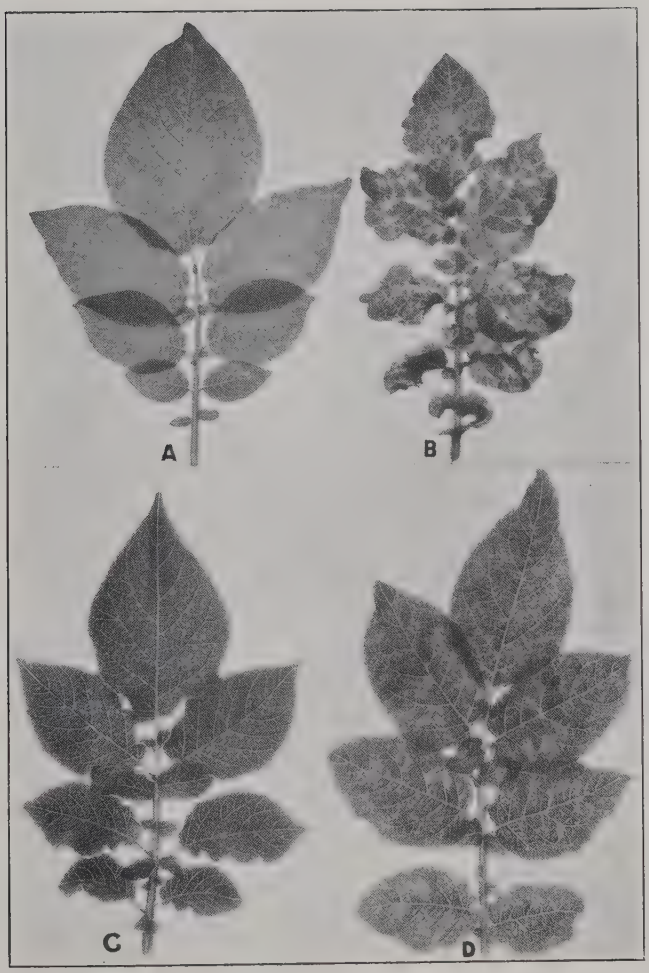
Plate VI. Showing the spread of virus diseases in a field planting of tomatoes at Pullman, Washington, in 1930. A. Inoculated 25 plants June 1, 1930, with tobacco mosaic. B. Inoculated 16 plants July 11, 1930 with the tobacco mosaic virus and the laten potato virus. Curly top was introduced by natural infection.

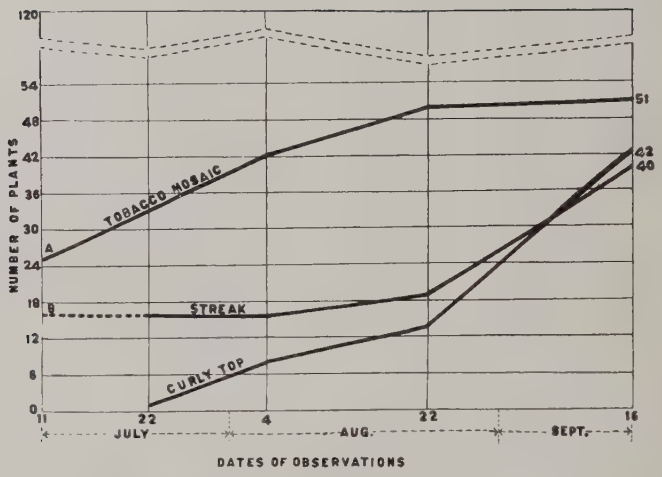

A²
B
C
D


A
B
C


A
B
C


A
B
C


A
B
C
D


120
54
48
42
36
30
24
18
12
6
0
NUMBER OF PLANTS
TOBACCO MOSAIC
A
STREAK
B
CURLY TOP
51
42
40
11
22
4
22
16
JULY
AUG.
SEPT.
DATES OF OBSERVATIONS

Five plants from hill B when inoculated with rugose mosaic produced typical rugose mosaic.

Five plants from hill A when inoculated with a combination of rugose mosaic and tobacco mosaic produced typical rugose mosaic but of greater severity than when rugose mosaic was used alone. This combination produced extreme necrosis, killing and dropping of the foliage and more severe stem streak on all 5 plants.

Five plants from hill B when inoculated with crinkle mosaic (carrying latent) gave rugose mosaic including necrosis, but of less severity than plants inoculated with rugose mosaic or the virulent latent virus.

Five plants from hill A were inoculated with crinkle mosaic (carrying latent) which had passed through a potato seedling and then through tobacco. These 5 plants produced rugose mosaic with mild leaf necrosis which is similar in all respects to the symptoms described in the previous paragraph.

One healthy plant from hill C was inoculated with the virulent latent virus and another healthy plant from hill C was inoculated with the virulent latent virus in combination with macerated foliage from a plant from hill D which carried the veinbanding virus. The first plant produced a mild mottle which approaches the mottle of mild mosaic. In addition, the foliage showed comparatively few very small, brown necrotic spots of the upper leaves, varying in size from mere specks up to 1 mm. in diameter. The second plant produced typical rugose mosaic symptoms, including stem streak and leaf necrosis.

Five plants from hill F, which were affected with rugose mosaic were inoculated with tobacco mosaic. These plants produced severe rugose mosaic symptoms but no more severe than other plants from tubers from the same source (hill F) which were not inoculated with tobacco mosaic.

Five plants from hill B, when inoculated with leaf roll (carrying latent) gave rugose mosaic similar to those inoculated with crinkle mosaic.

Five plants from hill A, were inoculated with spindle tuber (carrying latent) and 2 of the plants gave symptoms of rugose mosaic with necrosis.

When the virulent latent virus and crinkle mosaic (carrying latent) were combined and inoculated to 5 plants from hill A, very mild rugose and necrotic symptoms appeared on all plants. In several tests on tomato and tobacco this combined virus mixture produced much milder symptoms than the virulent latent virus alone, but slightly more pronounced than symptoms produced by the crinkle mosaic alone. It appears that the latent virus from crinkle mosaic produces an in-

hibitory effect on the expression of the virulent latent virus which was secured from dried rugose mosaic material.

Four tubers produced from hill E, and 5 from hill F, were indexed in the greenhouse. Tuber No. 6 from hill E produced an apparently healthy plant. Macerated foliage from this apparently healthy plant gave the characteristic mottle of the virulent latent virus on tomato and the ring and line pattern on tobacco (Table 6). The other 8 plants showed unquestionable symptoms of rugose mosaic and gave 100 per cent spot necrosis on tomato. When the foliage of each of the 8 plants showing rugose mosaic was used as inoculum in 8 separate series, of 5 tobacco plants each, spot necrosis (typical of rugose mosaic) was produced on 28 plants, and symptoms characteristic of the virulent latent virus on tobacco were produced on 12 plants (Table 6). These data show that the veinbanding virus was not transferred as readily as the virulent latent virus from the rugose mosaic complex. Smith (30) also has shown that a 60 to 70 per cent infection with the veinbanding virus when transferred by mechanical methods, is commonly obtained.

These investigations on the inoculation of plants produced from progeny of the healthy Early Rose potato, show that plants produced from this tuber are not resistant to the various virus diseases. The original tuber merely escaped infection.

THE USE OF MACERATED TUBER TISSUE AS INOCULUM

Previous tests have shown that practically all commercial tuber stock is infected with the latent virus. These tests were made by using macerated foliage tissue in combination with the tobacco mosaic virus. If such tests could be made by using macerated tuber tissue the work of testing tuber stock would be greatly facilitated. Accordingly, 6 apparently healthy tubers of the Early Rose variety, which had been tested and shown to carry the latent virus, were tested for viruses by using a portion of the macerated tuber in combination with tobacco mosaic. The results (Table 7) show that only 6 tomatoes gave streak symptoms, whereas, 22 showed only tobacco mosaic.

In a similar manner one tuber known to be infected with rugose mosaic and 5 tubers infected with leaf roll and the latent virus were tested on tomato using the macerated tuber alone and again in combination with tobacco mosaic. Of the 30 tomato plants inoculated, the results (Table 7) show 1 tomato with mottle, and no streak.

Comparing these results (Table 7) with other results, when the potato foliage was used as inoculum, it will be seen that only about a 10 per cent infection took place when macerated tuber was used in contrast to about 90 per cent infection when macerated potato foliage

was used. These tests show that it is not practical to use macerated tuber tissue in testing for the latent virus. Investigations by Johnson (19) were similar to the above in that he obtained only 38 per cent infection with the latent virus from macerated tuber tissue.

Table 7. Results of Inoculation Tests on Tomato with Macerated Tuber Tissue

Macerated tuber alone			Macerated tuber plus tobacco mosaic		
No. of tubers tested	No. of plants inoculated	No. of plants diseased	No. of tubers tested	No. of plants inoculated	No. of plants diseased
-	-	-	6[1]	30	6S 22T[2]
1[3]	5	0	1	5	5T
5[4]	25	1M	5	25	25T
6	30	1M	12	60	6S 52T

[1] Tubers from apparently healthy plants.
[2] M=Mottle; S=Streak; T=Tobacco mosaic.
[3] Tuber affected with rugose mosaic.
[4] Tubers affected with leaf roll.

COMPARATIVE SYMPTOMS AND LONGEVITY TESTS WITH VARIOUS VIRUS DISEASES OF POTATO

It has previously been shown that practically all apparently healthy commercial potato tubers are carriers of the latent virus or virulent latent virus. In order to make a comparison of the symptoms on tomato produced by certain known virus diseases of potatoes, preliminary tests which are recorded in Table 8 were made with macerated foliage of potatoes affected with the various virus diseases. When the foliage from 48 tubers was tested on 390 tomato plants, 305 exhibited a slight to a pronounced mottling, while 68 exhibited a slight to a pronounced spot necrosis. Four plants when inoculated with crinkle mosaic showed mild symptoms of spot necrosis, only on the inoculated leaves. Of the 135 tomato plants inoculated with rugose mosaic, 61 showed only a mottle, whereas, 68 plants showed both mottle and spot necrosis, many of which gave extreme symptoms with killing of the lower leaves.

When the fresh diseased potato foliage (representing 45 tubers) and tobacco mosaic were inoculated into 370 tomato plants, 359 developed streak, 6 developed only mottle and 5 showed spot necrosis. The results of these inoculations are similar to those secured when

the foliage from apparently healthy potatoes was used (Table 2), except that rugose mosaic produced more extreme symptoms of mottle and in addition usually produced spot necrosis of tomato. It is therefore concluded that the latent or virulent latent virus was present in all of the diseased tubers tested.

Table 8. Results of Inoculation Tests on Tomato with Fresh Foliage from Commercial Tubers Carrying Certain Virus Diseases

Source of inoculum and type of disease present	Potato foliage alone			Potato foliage plus tobacco mosaic		
	No. of trials	No. of plants inoculated	No. of plants diseased	No. of trials	No. of plants inoculated	No. of plants diseased
Crinkle mosaic	13	115	111M[1]	15	145	139S
			4SN[2]			6M
Leaf roll	10	95	93M	9	80	80S
Spindle tuber	3	20	20M	3	20	20S
Super-mild mosaic	1	5	5M	1	5	5S
Mild mosaic	2	10	10M	2	10	10S
Unmottled curly dwarf	1	5	5M	1	5	5S
Rugose mosaic	17	135	61M	13	100	95S
			64SN			5SN
Witches' broom	1	5	5M	1	5	5S
Totals	48	390	305M	45	370	359S
			68SN			6M
						5SN

[1] M=Mottle; S=Streak; SN=Spot necrosis.
[2] Mild symptoms only on inoculated leaves in this series.

A further comparative study of some of the more common virus diseases of the potato was made on tomato and tobacco. Tests were made with these viruses as follows: (1) fresh material directly from potato foliage; (2) fresh material after passing through tomato plants, tobacco plants or potato seedlings; and (3) the latter material after drying for different periods of time. An apparently healthy potato of the White Rose variety, tested and known to carry the latent factor was chosen as one source of inoculum. Rugose mosaic was secured from a Bliss Triumph potato, and leaf roll from a Burbank potato (Table 9). Spindle tuber was secured from a Bliss Triumph potato and crinkle mosaic from an Idaho Rural potato (Table 9). Following the inoculation with any given virus 5 tomato and 5 tobacco plants were used as controls (see Materials and Methods).

Fresh foliage produced from each of the five above mentioned diseased tubers was used as a source of inoculum and prepared and fractioned as previously outlined under "Materials and Methods." Each of the five potato viruses was used to inoculate a series consisting of 10 tomato, 10 tobacco and 10 potato seedlings. To another fraction of this inoculum fresh tobacco mosaic was added, and likewise used as inoculum to 10 tomato, 10 tobacco and 10 potato seedlings. From the results shown in Table 9 it will be noted that when tomato plants were inoculated with the macerated foliage, 100 per cent of the plants of each of the 5 series showed mottle characteristics of the latent virus disease. Plants inoculated with macerated foliage from potatoes carrying rugose mosaic showed extreme mottle and chlorosis and often showed considerable spot necrosis. Plants inoculated with inoculum from potatoes carrying leaf roll, spindle tuber and crinkle mosaic developed symptoms similar to those produced by the latent virus, although in many cases the mottling was more pronounced with a few plants showing mild spot necrosis.

Table 9. Results of Inoculation Tests to Tomato, Tobacco, and Potato Seedlings with Fresh Potato Leaf Tissue Affected with Various Virus Diseases

Source of inoculum	On tomato		On tobacco		On potato seedlings	
	Alone	Plus tobacco mosaic	Alone	Plus tobacco mosaic	Alone	Plus tobacco mosaic
Latent	10M[1]	10S	10M	10LN	10[2]	10
Rugose mosaic	10M (10SN)	10S	10SN	10LN	10	10
Leaf roll	10M (3SN)	9S 1M	10M	10LN	10	10
Spindle tuber	10M	9S 1T	6M 4LN[3]	10LN	10	10
Crinkle	10M (1SN)	10S	10M	10LN	10	10

[1] M=Mottle; S=Streak; LN=Leaf necrosis; SN=Spot necrosis; T=Tobacco mosaic. The figures indicate the number of plants showing the symptoms recorded.

[2] Symptoms on potato seedlings not readily discernible at the time notes were taken and foliage taken as a source of inoculum for subsequent series.

[3] Contamination with tobacco mosaic—will be noted with all subsequent inoculations in Tables 10, 11, and 12, with this source of inoculum.

When tobacco mosaic was added to a fraction of each of the above five sources of inoculum from potato, only 2 tomato plants of the 50 failed to show streak and of these 2, 1 showed the presence of the latent virus and the other showed the presence of tobacco mosaic. This shows that nearly 100 per cent infection with the latent virus was obtained from fresh potato foliage on tomato.

In a similar manner, each of 5 series of 10 young tobacco plants was inoculated with 1 of the 5 potato viruses mentioned above. From the table it will be noted that plants inoculated with latent, leaf roll and crinkle mosaic gave a mottle, while those inoculated with rugose showed 100 per cent spot necrosis. When plants were inoculated with spindle tuber 60 per cent showed the similar mottle as characterized by the latent virus while 40 per cent showed a leaf necrosis. At the time the leaf necrosis symptoms appeared it was believed that 4 of the plants had been contaminated with tobacco mosaic. With further tests on tomato and tobacco this conclusion was substantiated.

To a fraction of the inoculum, from each of the 5 potato plants tobacco mosaic was added and 5 series of tobacco plants, of 10 plants each, were inoculated with these combined virus mixtures. Again referring to Table 9, it will be noted that 100 per cent of the plants showed leaf necrosis, which is the characteristic symptom of the combination of latent virus and tobacco mosaic on tobacco.

A similar set of potato seedlings was inoculated as those of tomato and tobacco, using the fresh inoculum from each of the 5 potato plants, at first alone, and again in combination with tobacco mosaic. Under the conditions of the experiment, it was impossible to determine, by observation, the disease present in the potato seedlings, but the foliage from these plants was dried and used in further tests as inoculum the same as for tomato and tobacco.

At the time symptoms had developed sufficiently on tomato and tobacco to be certain of the results, fresh foliage was taken from each of the inoculated series and subsequent inoculations were made. Fresh foliage was taken from one or more plants of each series and used as inoculum to 5 tomato and 5 tobacco plants. Two plants from each of the original series were retained for further observation and comparisons with all subsequent series made with this source of inoculum. Further inoculations were made with the dried leaf tissue from the other 8 plants of each series. These plants were dried in paper bags in an incubator for 3 days at a constant temperature of 32° C. When the foliage was thoroughly dry, care was taken to crumble all of the leaf tissue. The dried and macerated foliage from each separate series was used for inoculum in subsequent inoculation series after being dried 10 and 46 days respectively. Tabulated results are shown in Tables 10, 11 and 12. In making the inoculations, about 1 gram of the crumbled leaf tissue was poured out of the paper bag into a mortar which had been thoroughly washed with soap and water. The leaf tissue was then macerated and about 10 cc. of tap water added and the material again macerated.

The results of these inoculation series are practically identical with those shown in Table 9, when the inoculum was taken directly from

fresh material from diseased potato plants. In general, the fresh inoculum gave almost 100 per cent infection, whereas, the dried inoculum, as shown by Tables 10, 11 and 12 often gave a lower percentage of disease. This, no doubt, can be explained by the fact that the virus had become less virulent or even killed under desiccation.

Table 10. Results of Inoculation Tests with Various Potato Virus Diseases in Fresh and Dried Leaf Tissue on Tomato and Tobacco[1]

Source of inoculum	On tomato			On tobacco		
	Fresh material	Dried		Fresh material	Dried	
		10 days	46 days		10 days	46 days
Through tomato:						
Latent	5M[2]	5M	5M	5M	2M 1R	0
Rugose mosaic	5SN	2SN 2M	5M	5SN	2M 3R	4M 1R
Leaf roll	5M	4M	5M	5M	5M	4M 1R
Spindle tuber	5M	5M	5M	5M	3M 2R	5M
Crinkle	5M	5M	5M	5M	5M	5M
Through tobacco:						
Latent	5M	5M	5M	5M(5R)	1M 4R	2M
Rugose mosaic	5SN	4SN	5M	5SN	5SN	5SN
Leaf roll	5M	2M	5M	5M	5M	4M
Spindle tuber[3]	5S	4S	3S	5LN	5LN	5LN
Crinkle	5M	5M	5M	5M	5M	4M 1R
Through potato seedlings:						
Latent	5M	5M	4M	5M	3M 2R	1M
Rugose mosaic	2M 2SN	0	0	5SN	0	2M
Leaf roll	5M	5M	5M	5M	5M	5M
Spindle tuber	0	5M	5M	0	5M	4M 1R
Crinkle	4M	5M	5M	5M	5M	4M 1R

[1] Five plants were used in each series.

[2] M=Mottle; R=Virulent latent; SN=Spot necrosis; S=Streak; LN=Leaf necrosis. The figures indicate the number of plants showing the symptoms recorded.

[3] Tobacco mosaic contamination as noted in Table 9.

Table 11. Results of Inoculation Tests on Tomato and Tobacco Plants with Fresh and Dried Plant Tissue Previously Inoculated with Various Potato Virus Diseases to which Fresh Tobacco Mosaic Was Added at the Time of Inoculation[1]

Source of inoculum	On tomato			On tobacco		
	Fresh material	Dried		Fresh material	Dried	
		10 days	46 days		10 days	46 days
Through tomato:						
Latent	5S[2]	3S 2T	5S	5LN	4LN 1T	5LN
Rugose mosaic	5S	4S 1T	4S 1T	5LN	5LN	5LN
Leaf roll	5S	4S	4S 1T	5LN	5LN	5LN
Spindle tuber	5S	4S 1T	3S 2T	5LN	5LN	5LN
Crinkle	5S	2S 3T	4S 1T	5LN	5LN	4LN 1T
Through tobacco:						
Latent	5S	5S	1S 4T	5LN	5LN	5LN
Rugose mosaic	5S	4S 1T	4S 1T	5LN	4LN	5LN
Leaf roll	5S	3S 2T	4S 1T	5LN	5LN	4LN 1T
Spindle tuber	5S	4S	4S 1T	5LN	5LN	5LN
Crinkle	4S	3S 2T	1S 4T	5LN	2T	3LN 2T
Through potato seedlings:						
Latent	5S	2S 3T	1S 4T	5LN	5T	1LN 4T
Rugose mosaic	5T	5T	5T	3LN2T	5T	5T
Leaf roll	5S	4S 1T	5S	5LN	5LN	5LN
Spindle tuber	5T	4S 1T	5S	5T	5LN	5LN
Crinkle	5S	5S	5S	5LN	5LN	4LN 1T

[1] Five plants were used in each series.

[2] S=Streak; T=Tobacco mosaic; LN=Leaf necrosis. The figures indicate the number of plants showing the symptoms recorded.

Analyses of Tables 10, 11 and 12 show that the latent virus was present in the apparently healthy and the four diseased potato plants tested. It also shows that a high percentage of infection was obtained with either the fresh or dried material and that the latent virus remained active in dried plant tissue for at least 46 days. It will be noted that the apparently healthy, leaf roll, spindle tuber and crinkle mosaic potatoes produced the characteristic mottle of the latent virus or the ring and line pattern of the virulent latent virus. It is also shown that the latent virus, to which fresh tobacco mosaic was added at the time of inoculation (Table 11), produced streak of tomatoes and leaf necrosis of tobacco.

Table 12. Results of Inoculation Tests on Tomato and Tobacco with Fresh and Dried Plant Tissue Inoculated with Various Potato Virus Diseases and Tobacco Mosaic[1]

Source of inoculum	On tomato			On tobacco		
	Fresh material	Dried		Fresh material	Dried	
		10 days	46 days		10 days	46 days
Through tomato:						
Latent	5S[2]	5S	5S	5LN	5LN	5LN
Rugose mosaic	5S	4S 1T	4S 1T	5LN	5LN	3LN 2T
Leaf roll	5S	1S 4T	1S 4T	5LN	3LN 2T	4LN 1T
Spindle tuber	5S	5S	2S 3T	5LN	5LN	4LN 1T
Crinkle	5S	5S	4S 1T	5LN	5LN	5LN
Through tobacco:						
Latent	5S	3S 2T	2S 3T	5LN	5LN	3LN 2T
Rugose mosaic	5S	5S	1S 4T	5LN	3LN 2T	5T
Leaf roll	5S	1S 3T	1S 4T	5LN	5LN	5LN
Spindle tuber	5S	3S 2T	1S 4T	5LN	5LN	4LN 1T
Crinkle	4S	3S 2T	5T	5LN	5LN	4LN
Through potato seedlings:						
Latent	2T	4S 1T	5S	5T	5LN	5LN
Rugose mosaic	1S 4SN	5SN	5M	4LN 1M	3LN 2R	4M 1R
Leaf roll	5S	3S	5S	5LN	5LN	4LN
Spindle tuber	1S 4M	1S 4M	3T	4LN 1M	4LN 1M	5T
Crinkle	0	3S 2M	3S 2T	2M 2T	5LN	5LN

[1] Five plants were used in each series.

[2] S=Streak; LN=Leaf necrosis; T=Tobacco mosaic; M=Mottle; R=Virulent latent. The figures indicate the number of plants showing symptoms recorded.

The combined virus mixture, latent virus plus tobacco mosaic virus, after passing through tomato, tobacco or potato seedlings, likewise produced streak of tomato and leaf necrosis of tobacco. This shows that the latent virus when used alone or when combined with the tobacco mosaic virus remained active in tomato, tobacco or potato seedling tissue for at least 46 days.

From the symptoms recorded in Tables 10, 11 and 12, it is apparent that the latent virus was the only virus transmitted from the apparently healthy, leaf roll, spindle tuber, or crinkle mosaic affected potatoes that produced symptoms on tomato or tobacco. When a rugose-mosaic-affected potato plant was used as the source of fresh

inoculum, spot necrosis was produced in nearly 100 per cent of the tests. This indicates that the veinbanding virus as well as the latent virus was transmitted. The tests also show that the veinbanding virus may commonly live 10 days in dried plant tissue. The veinbanding virus remained active in tobacco tissue, but was inactive in tomato and potato tissue, which had been dried 46 days. When the veinbanding virus was inactivated by drying the rugose mosaic infected tissue, the latent virus remained active.

In several cases with seedling potatoes, no viruses were transmitted. This may be explained by the fact that the individual plants used as a source of inoculum were not infected by the viruses at the time of the original inoculations. As previously noted the symptoms of virus diseases did not develop readily on seedling potatoes. Even though symptoms did not appear, it was deemed advisable to use the young seedlings in order to complete the series of tests.

Further tests were made to determine the length of time the latent or the virulent latent virus would remain active in dried tissue. Various plants known to be infected with the latent virus were dried at room temperature in paper bags and inoculations were made to tomato and tobacco at intervals as noted in Table 13.

The latent virus that occurred in the plants affected with crinkle mosaic and leaf roll appears, in general, (Table 13) to be inactivated prior to 77 days of drying, with the exception of 2 plants out of 80 that had been inoculated with material which had been dried 200 days. The latent virus as found in rugose-mosaic-infected potato plants gave about a 20 per cent infection on tomato or tobacco after being dried in tomato leaf tissue for a period of 286 days. Somewhat similar percentages of infection were obtained with the latent virus after being dried in tomato leaf tissue 200 and 233 days respectively. It is shown in Table 13, that streak, which is a combination of the tobacco mosaic virus and the latent or the virulent latent virus, when dried in tomato leaf tissue may still be infective after 77, 233, 286, and 466 days. The infection obtained from this dried material varied from 3 to 20 per cent in contrast to nearly 100 per cent infection commonly obtained by the use of fresh material as the source of inoculum.

A summary of symptoms produced by various virus diseases on tomato, tobacco and potato plants is recorded in Table 14.

Table 13. Results of Longevity Tests of the Latent Virus when Dried at Room Temperature in Tomato Leaf Tissue and Reinoculated in Tomato or Tobacco Plants

Host inoculated and type of virus[1]	Number of days dried				
	77	200	233	286	466
Crinkle mosaic	2-10[2]	4-40		2-20	
	0	1M		0	
Crinkle plus tobacco mosaic	2-10	4-40		2-20	
	10T	1S 38T		20T	
Leaf roll	2-10			1-10	
	0			0	
Leaf roll plus tobacco mosaic	1-5			1-10	
	5T			10T	
Rugose mosaic: On tomato		3-30	1-10	1-20	
		3SN 3M	2M	3M 1SN	
On tobacco				1-20	
				6R	
Rugose mosaic plus tobacco mosaic: On tomato		3-30	1-10	1-20	
		1S 29T	1S 9T	3S 17T	
On tobacco				1-20	
				3LN 17T	
Streak—various sources	16-130		7-55	14-135	3-30
	25S 103T		6S 49T	4S 131T	6S 24T

[1] All inoculations made in tomato plants except as noted.

[2] First number of numerator represents total number of series; second number total number of plants used, and the denominator represents the number of plants affected and type of disease. M=Mottle; S=Streak; T=Tobacco mosaic; SN=Spot necrosis; R=Virulent latent; LN=Leaf necrosis.

Table 14. Summary Tabulation of the Symptoms and Effects of Certain Viruses on Tomato, Tobacco and Potato Plants when Used Alone or in Various Combinations

Virus	Virus	Symptoms produced on host		
		Tomato	Tobacco	Potato
Latent +	0	Mottle	Mottle	0
	Tobacco mosaic	Streak (moderate)	Leaf necrosis	Spot necrosis or 0
	Tobacco veinbanding	Spot necrosis	Spot necrosis	Rugose mosaic
	Virulent latent	Mottle or slight necrosis	Mottle or ring and line	Spot necrosis or 0
Tobacco mosaic + "Type 1"	0	Mosaic	Mosaic	Spot necrosis or 0
	Veinbanding	Mosaic	Mosaic	Not tested
	Virulent latent	Severe streak	Severe leaf necrosis	Not tested
Veinbanding +	0	Faint mottle?	Veinbanding	Mottle crinkling
	Virulent latent	Severe spot necrosis	Severe spot necrosis	Severe rugose mosaic
	Virulent latent and tobacco mosaic	Severe streak	Severe leaf necrosis	Malignant rugose mosaic
Virulent latent	0	Mottle, spot necrosis	Mottle ring and line	Mild spot necrosis

THE SPREAD OF CERTAIN VIRUS DISEASES OF TOMATO IN THE FIELD

The spread of virus diseases in a field planting of tomatoes at Pullman, Washington, during the summer of 1930, is shown graphically in Plate VI. The plot consisted of 15 rows of 8 plants each. The rows were placed 5 feet apart with a spacing of 5 feet between the plants within the row. Potted plants which were strong and healthy were set in the field on June 1. Twenty-five plants, at random over the entire field, were inoculated with tobacco mosaic on June 1. On July 11, 8 plants in row 3 were inoculated with a combination of the latent virus from a leaf roll affected potato plant and tobacco mosaic, and 8 plants in row 13, were inoculated with rugose mosaic of potato and tobacco mosaic. The number of plants affected with tobacco mosaic alone, gradually increased from 25 on July 11 to 50 on August 22, with one additional plant by September 16.

The 16 plants which were inoculated with the combined viruses on July 11 showed streak symptoms on July 22.

Picking began on August 4. On August 22, a total of 19 plants showed streak. Throughout the picking season the amount of disease increased until on September 16 a total of 40 plants had developed streak and 51 showed only tobacco mosaic. Definite record was not taken after September 16, but nearly 100 per cent of the plants had developed streak by October 10.

Natural infection of curly top by the beet leaf hopper, *Eutettix tenellus* Baker, was evident on one plant on July 22. On September 16, 42 plants showed curly top symptoms. In a number of cases the plants were completely killed by this disease.

In view of these results, it may be concluded that insects as well as cultural practices are responsible for the spread of tobacco mosaic under field conditions. It would appear, however, that the latent virus of potatoes and streak are only spread by contact and injury to the foliage due to cultural and harvesting practices.

Late infection of tomato plants with streak does not materially affect the yield of fruit and for that reason may be of minor importance under ordinary field conditions. The reverse may be true with early infection and especially if the plants are brushed and injured during cultivation or other field operations.

SUMMARY

Experimental results are presented showing the effect of certain potato and tobacco viruses on tomato plants when used alone or in various combinations.

Tests were made to determine the prevalence of the latent virus in potato plants produced from commercial tubers as well as from true seed. Of the 655 tubers tested, representing six commercial varieties, only one was found to be free from the latent virus. The latent virus was not present in the 52 seedling potato plants that were tested. Progeny of the healthy tuber showed no resistance to the common virus diseases, hence it is probable that the healthy tuber had merely escaped infection.

The veinbanding virus plus the virulent latent virus produced spot necrosis of tomato and tobacco and produced symptoms very similar to rugose mosaic of potato.

A discussion is presented of the preliminary results on the effect of various viruses upon healthy and veinbanding-virus-infected Early Rose potatoes. When potato plants, carrying the veinbanding virus, were inoculated with the virulent latent virus, symptoms very similar to rugose mosaic were produced. The progeny from the virus-free Early Rose potato when inoculated with rugose mosaic produced typical rugose mosaic symptoms. When tobacco mosaic was added to rugose mosaic and inoculated to plants affected with the veinbanding virus a more severe type of rugose mosaic was produced than when rugose mosaic alone was used as the inoculum, However, the inoculation with tobacco mosaic on plants already affected with rugose mosaic did not affect the rugose symptoms expressed by the plant.

The Early Rose potato plants carrying the veinbanding virus showed a mild type of rugose mosaic when inoculated with inoculum from potato plants affected with crinkle mosaic, leaf roll or spindle tuber (all carrying the latent virus).

The virulent latent virus produced a mild mottle with some necrosis on one of the virus-free Early Rose potato plants. The virulent latent virus plus the veinbanding virus on the virus-free Early Rose potatoes, produced rugose mosaic symptoms including stem streak and leaf necrosis.

The virulent latent virus in combination with the crinkle mosaic virus (carrying a mild latent virus) often produced much milder symptoms on potato, tomato, or tobacco than did the virulent latent virus when used alone. The latent virus from crinkle mosaic seems to produce an inhibitory effect on the expression of the virulent latent virus.

The veinbanding virus was not as readily transmitted mechanically as was the latent virus.

Tests show that it is not practical to use macerated tuber tissue in testing for the presence of the latent virus.

The latent or virulent latent virus was found to be present in 48 tubers that showed symptoms of the following virus diseases: crinkle mosaic, leaf roll, spindle tuber, super-mild mosaic, mild mosaic, unmottled curly dwarf, rugose mosaic and witches' broom.

Inoculum from apparently healthy potatoes (carrying the latent virus) produced similar symptoms on tomato and tobacco plants as did inoculum from potato plants carrying leaf roll, spindle tuber or crinkle mosaic, while rugose mosaic inoculum gave additional symptoms of chlorosis and spot necrosis. When tobacco mosaic was added to inoculum from any of these sources, streak of tomato and leaf necrosis of tobacco were produced.

Fresh inoculum from potato plants produced a higher per cent of infection on tomato and tobacco plants than was secured when the inoculum was dried for different periods of time.

The latent virus when used alone or when combined with the tobacco mosaic virus remained active in dried tomato, tobacco or potato seedling tissue for at least 46 days. This virus also remained sufficiently active in tomato plant tissue which had been dried 466 days to insure a 20 per cent infection.

The latent virus appeared to be the only virus transmitted mechanically to tomato or tobacco from the apparently healthy, leaf roll, spindle tuber or crinkle mosaic affected potatoes, while the veinbanding virus in addition, was transmitted from rugose mosaic affected potatoes.

The veinbanding virus commonly remains active 10 days in dried plant tissue and was found to remain active in dried tobacco leaf tissue for 46 days.

It is apparent that the latent or virulent latent virus is capable of producing a lethal effect on tomato, tobacco or potato and that this lethal effect is materially intensified when found in combination with tobacco mosaic.

It appears that under field conditions, tobacco mosaic may be spread by insects and mechanical means and that the latent virus is only spread by mechanical means.

LITERATURE CITED

1. Allard, H. A., The Mosaic disease of tomatoes and petunias. Phytopath. **6:** 328-335. 1916.
2. Bailey, L. H., Some troubles of winter tomatoes. I. Winter blight. N. Y. (Cornell) Agr. Exp. Sta. Bul. **43:** 149-158. 1892.
3. Berkeley, G. H., Studies in tomato streak. Sci. Agr. **7:** 210-223. 1927.
4. Blood, H. L., A "Streak" of tomatoes produced by a disturbing principle from apparently healthy potatoes in combination with tomato mosaic virus. Phytopath. **18:** 311. 1928.
5. Brittlebank, C. C., A new tomato disease. Jour Dept. Agr. Victoria. **17:** 231-235. 1919.
6. Burnett, G. and L. K. Jones, In contrast with seedling stock, apparently healthy potato tubers are virus carriers. (Abstract) Phytopath. **20:** 854-855. 1930.
7. ———, ———, The distribution of the latent virus in tubers of commercial potatoes. (Abstract) Phytopath. **21:** 104. 1931.
8. Clinton, G. P., Notes on fungous diseases, etc. for 1908. Conn. Agr. Exp. Sta. Bien. Rept. **1907-1908:** 857-858. 1908.
9. Dickson, B. T., Tobacco and tomato mosaic. (2) Streak of tomato in Quebec a double-virus disease. Science **62:** 398. 1925.
10. Doolittle, S. P. and H. L. Blood, Investigations of tomato streak. (Abstract) Phytopath. **20:** 134. 1930.
11. Fernow, K. H., Interspecific transmission of mosaic diseases of plants. N. Y. (Cornell) Agr. Exp. Sta. Mem. **96:** 3-34. 1925.
12. Gardner, M. W. and J. B. Kendrick, Tomato mosaic. Ind. Agr. Exp. Sta. Bul. **261:** 1-24. 1922.
13. Henderson-Smith, J., The transmission of potato mosaic to tomato. Ann. Appl. Biol. **15:** 517-528. 1928.
14. Howitt, J. E. and R. E. Stone, A troublesome disease of winter tomatoes. Phytopath. **6:** 162-166. 1916.
15. Jackson, H. S., Tomato diseases. Ind. (Purdue) Agr. Exp. Sta. Ann. Rept. **30:** 23. 1917.
16. Jarrett, Phyllis H., Streak—A virus disease of tomatoes. Ann. Appl. Biol. **17:** 248-259. 1930.
17. ———, The role of *Thrips tabaci* Lindeman in the transmission of virus diseases of tomato. Ann. Appl. Biol. **17:** 444-451. 1930.
18. Johnson, E. M., Virus diseases of tobacco in Kentucky. Ky. Agr. Exp. Sta. Res. Bul. **306:** 289-415. 1930.
19. Johnson, James, Transmission of viruses from apparently healthy potatoes. Wis. Agr. Exp. Sta. Res. Bul. **63:** 1-12. 1925.
20. ———, The classification of plant viruses. Wis. Agr. Exp. Sta. Res. Bul. **76:** 1-16. 1927.
21. ———, The classification of certain virus diseases of the potato. Wis. Agr. Exp. Sta. Res. Bul. **87:** 1-24. 1929.
22. Melhus, I. E., Mosaic studies. Phytopath. **12:** 42. 1922.
23. Olitsky, P. and J. H. Northrop, The inoculation of tomato and tobacco plants with potato virus. Science **61:** 544-545. 1925.

24. Orton, C. R. and W. H. McKinney Jr., Winter blight of the tomato. Pa. Agr. Exp. Sta. Ann. Rept. **1914-1915:** 235-246. 1915.
25. Paine, S. G. and W. F. Bewley, Studies in bacteriosis IV. "Stripe" disease of tomato. Ann. Appl. Biol. **6:** 183-203. 1919.
26. Quanjer, H. M., General remarks on potato diseases of the curl type. Rept. Int. Conf. of Phytopath. and Ent. **1923:** 23-28. H. Veeman & Sons, Wageningen, Holland. 1923.
27. Samuel, G., J. G. Bald, and H. A. Pittman, Investigations on "spotted wilt" of tomatoes. Council for Sci. and Ind. Res. Bul. **44:** 1-64. Melbourne, Australia. 1930.
28. Schultz, E. S. and Donald Folsom, Transmission, variation, and control of certain degeneration diseases of Irish potato. Jour. Agr. Res. **25:** 43-115. 1923.
29. ———, ———, Infection and dissemination experiments with degeneration diseases of potatoes. Observations in 1923. Jour. Agr. Res. **30:** 493-528. 1925.
30. Smith, Kenneth M., Studies on potato virus diseases. IV. Further experiments with potato mosaic. Ann. Appl. Biol. **16:** 1-32. 1929.
31. ———, Studies on potato virus diseases. V. Insect transmission of potato leaf-roll. Ann. Appl. Biol. **16:** 209-229. 1929.
32. ———, Studies on potato virus diseases. VI. Further experiments with the virus of a potato mosaic upon the tobacco plant. Ann. Appl. Biol. **16:** 382-399. 1929.
33. ———, Studies on potato virus diseases. VIII. Some experiments with the virus of a potato crinkle with notes on interveinal mosaic. Ann. Appl. Biol. **17:** 223-240. 1930.
34. Stone, R. E., Winter blight or streak in tomatoes. (Abstract) Phytopath. **15:** 300. 1925.
35. Stover, W. G., Experiments with tomato streak. (Abstract) Phytopath. **18:** 154. 1928.
36. Valleau, W. D., The viruses concerned in rugose mosaic of Irish Cobbler potatoes and the weed-host problem. (Abstract) Phytopath. **20:** 135. 1930.
37. ———, and E. M. Johnson, Some virus diseases of tobacco in Kentucky. (Abstract) Phytopath. **18:** 132-133. 1928.
38. ———, ———, The relation of some tobacco viruses to potato degeneration. Ky. Agr. Exp. Sta. Res. Bul. **309:** 475-507. 1930.
39. ———, ———, Some possible causes of streak in tomatoes. Phytopath. **20:** 831-839. 1930.
40. Vanterpool, T C., Streak or winter blight of tomato in Quebec. Phytopath. **16:** 311-331. 1926.
41. Westerdijk, Johanna, Die mosaikkrankheit der tomaten. Meded. Phytopath. Lab. "Willie Commelin Scholten," Amsterdam **1:** 1-19. 1910.
42. Young, P. A. and H. E. Morris, Witches' broom of potatoes and tomatoes. Jour. Agr. Res. **36:** 835-854. 1928.
43. ———, ———, Researches on potato-virus diseases in Montana. Mont. Agr. Exp. Sta. Bul. **231:** 1-51. 1930.